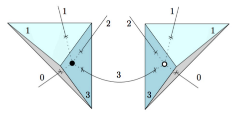
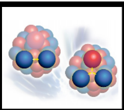
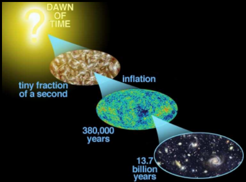
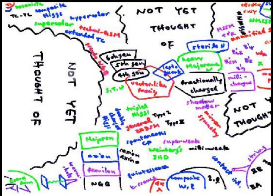
HCERES evaluation of Laboratoires de la vallée d'Orsay

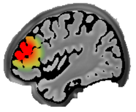
CSNSM
IMNC
IPNO
LAL
LPT











Theoretical Physics

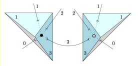
Speaker : Bartjan van Tent
For all the theorists of the LPT, IPN, IMNC, LAL

14-17 january 2019

THEORY
is everywhere!

7.

1.



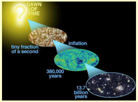
1. **Mathematical physics**
2. **Cosmology & gravitation**
3. **Higgs sector & physics beyond the Standard Model (BSM)**
4. **Quantum chromodynamics (QCD) and flavour physics**
5. **Nuclear physics**
6. **Statistical physics**
7. **Interface physics - life sciences**

Cellular transport

6.

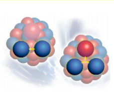
Quantum gravity

2.



Dark matter

5.



QCD

4.

(*)

3.

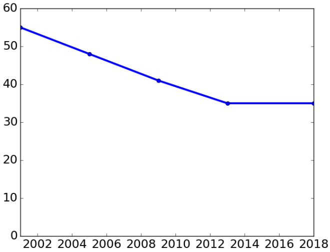
(*) flavour physics anomalies

Theory — **Human resources**

June 2018: **39 permanent scientists** (24 CNRS, 15 University)

During 2013-2018: 12 emeritus PR/DR, 31 postdocs, 120 internships,
58 PhD students (incl. joint supervision with other universities),
of which 37 have defended, so 21 remain in June 2018.

Evolution of permanent theorists LPT & IPN:



Huge number of retirements in past years, that have not been compensated by more recruitments. There will be 6 more retirements in the next five years.

Theory — **a few more numbers for the past 5 years**

Publications: **840** (refereed journals)

Conferences: **150** co-organized (65 as primary organizers)
also: weekly seminars, journal clubs, colloquia

Prizes: **7** (for permanent members)

Grants: 1 ERC, 2 ITN, 3 ANR, Labex (7 partial postdoc/PhD + small grants), many international bilateral EU/CNRS contracts (RISE, TWINNING, ECOS, PHC, PICS, . . .),
other small CNRS/regional grants (PNCG, PEPS, GEFLUC, DIM, . . .)

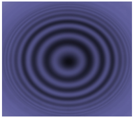
Collaborators: many, all over the world (> 30 countries)

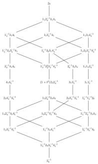
Teaching: 15 University staff (+ some CNRS) teach at all levels: L1-3, M1-2, ED
also: responsability & development of major courses & specializations (e.g. in L3-M1 Magistère de Physique Fonda., M1 General Physics, M2 Physique et Systèmes Biologiques, Agrégation de Physique)

Outreach: popular science books/articles, blog, websites, newspaper/radio interviews, debates general public, MOOCs, high school science for disabled pupils, AIMS-Senegal, computer codes

Mathematical physics — list of research topics:

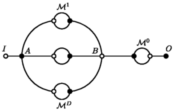
- Quantum spaces, structures and related field theories:
  QFT on quantum space-times, causality structures and renormalization properties



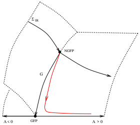


- Quantum groups and their representation theory, integrability:
  quantum affine algebras, quantum toroidal algebras and their representations

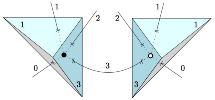
- Random tensors / quantum gravity:
  the *tensor track* approach to quantum gravity

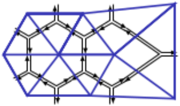


- Weinberg's asymptotic safety scenario for quantum gravity,
  studied by functional renormalization group methods



Highlight: **random tensor models**





- Matrix models: long history, many applications, e.g. way to sum over surfaces ⇒ they define quantum gravity in 2D. Large-N expansion is topological.
- **Tensor models**: natural generalization to higher rank, way to sum over higher dimensional manifolds ⇒ possible approach to quantum gravity.
- Not much progress for 20 years due to lack of large-N expansion, until:

Our group established the large-N expansion for non-symmetric models in 2011.

- In 2016: unexpected connection between tensor models and holographic model of black holes highlighted by Witten, increasing general interest in tensor models, and reviving question of large-N limit for symmetric tensors.

Our group obtained the large-N limit for symmetric-traceless tensor models in 2017.

Mathematical physics — **Outlook / plans**:

Summary: further pursue and expand the current research activities.
A few particular highlights:

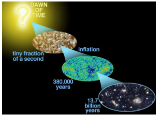
- **Field theories on 3+1-dimensional κ-Minkowski quantum space**: recent breakthrough in our group will finally allow studying of renormalization and causality properties + identifying observable consequences of their invariances.
- **Quantum toroidal algebras**: classifying their quasi-finite representations, with consequences e.g. for study of integrable systems and for solving quantum many-body systems (algebraic Bethe ansatz).
- **Applications of random tensors**: further progress towards theory of quantum gravity, but also in:
  - Already started: statistical mechanics, condensed matter and turbulence.
  - Next: big data analysis, artificial intelligence, image and video analysis.

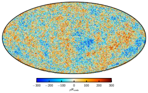
Cosmology & gravitation — list of research topics:

Modifications of gravity: construction/investigation of theories/models to explain acceleration of universe (current/inflation), consistency with local tests of GR.

Classical & quantum aspects of black holes: solutions and their stability in higher dimensions/modified gravity, Hawking radiation emitted by analogue black holes in condensed matter experiments

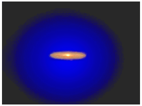
Primordial universe: multiple-field inflation, non-linear cosmological fluctuations.





Cosmic microwave background (CMB): estimator development, non-Gaussianities, Planck satellite.

Dark matter: models for production in the early universe, influence on process of reheating after inflation.



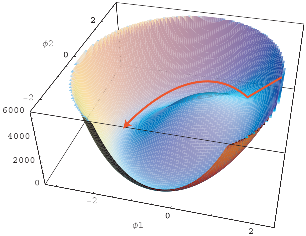
Highlight: **Constraints on inflationary non-Gaussianities using CMB data**

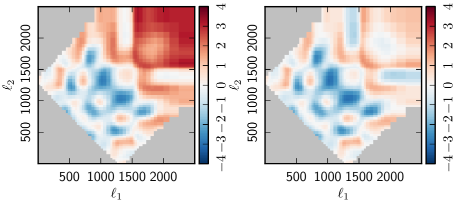
Linear treatment of cosmological density fluctuations produced during inflation ⇒ Gaussian distribution ⇒ CMB power spectrum contains all information.

However, certain inflation models, e.g. with multiple scalar fields, produce significant **non-linear** corrections:

$\Phi_{NL} = \Phi_L + f_{NL}\Phi_L^2 \Rightarrow \langle\Phi\Phi\Phi\rangle \sim f_{NL}\langle\Phi_L^2\rangle^2 \Rightarrow$ **non-Gaussianities**, non-zero bispectrum.

We developed an **estimator** to determine these f_{NL} parameters and applied it to the CMB data of the Planck satellite (→ see Astroparticles & Cosmology presentation), constraining these inflation models.

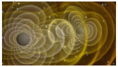




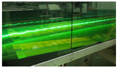
Cosmology & gravitation — **Outlook / plans**:

Summary: further pursue and expand the current research activities.
A few particular highlights:

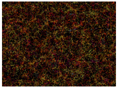
- **Modified gravity**: study impact of current and future gravitational wave detections by working out theoretical predictions for observables.



- **Analogue gravity**: set up more experimental collaborations to investigate analogues of Hawking effect and of preheating phase after inflation in condensed matter systems.



- **CMB/large-scale structure**: prepare for future CMB experiments after Planck (space + ground) and branch out to non-Gaussianity research for galaxy surveys.

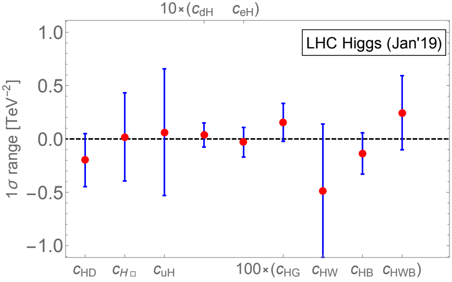


- **Dark matter**: study dependence on inflationary models of dark matter production and signatures.

Higgs sector & physics BSM — list of research topics:

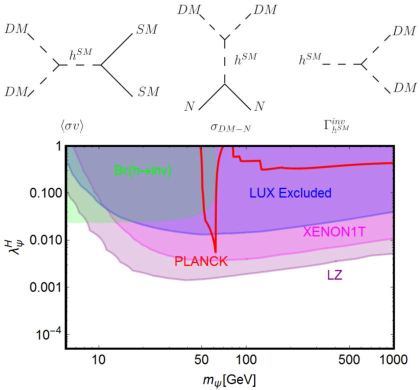
- **Collider physics**
  - Properties of the Standard Model Higgs boson
  - Effective field theory (EFT) approach to physics BSM
- **Neutrino physics, dark matter searches**
  - Scenarios with sterile neutrinos: leptogenesis, dark matter
  - Dark matter detection in SO(10) unified models and supergravity
- **Specific scenarios of physics BSM**
  - Study of supergravity at high energies
  - Exploring the parameter space of NMSSM and of 2HDM
  - Phenomenology in theories with (warped) extra dimensions
  - Scenarios with low energy leptoquarks
- **New physics through precision measurements at low energies**

Highlight: **Figuring out LHC Higgs and Higgs-portal dark matter**



Effective field theory framework

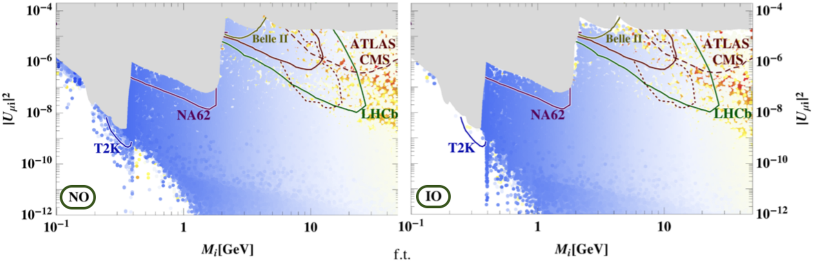
- $\mathcal{L}_{\rm SMEFT} \supset \mathcal{L}_{\rm SM} + \sum_i c_i \, \mathcal{O}_i^{(d=6)}$
- Combining various experimental constraints to probe $c_i \neq 0$ [$c_i \propto 1/\Lambda_{\rm NP}^2$]



- Constraints on dark matter mass and its coupling to SM Higgs (portal)
- Cases of DM particles being scalars, fermions or vector bosons

Highlight: **Baryon asymmetry of the universe (BAU) via testable leptogenesis**

Scenario: SM $+ 3\,\nu_R$ $(M_i < \Lambda_{\rm EW})$
explains neutrino masses, lepton mixing (PMNS) and BAU



- Sterile/active ν-mixing parameter for viable BAU as a function of mass of ν_R
- Gray region excluded by experiment
- Collider experiments help
- NO = Normal ordering of light neutrino masses (IO = Inverted ordering)

Higgs sector & physics BSM — **Outlook / plans**:

- **Collider phenomenology**
  - Signatures of BSM physics in future colliders
  - Further studies of the Higgs sector
- **Neutrino physics**
  - Testable leptogenesis
  - Study of ultra-energetic neutrinos as probes of physics BSM
- **Flavour beyond Standard Model**
  - Precision tests of SM through low-energy experiments (EFT)
  - Model building (leptoquark scenarios, compositeness, warped extra dimensions)
- **Formal aspects**
  - Formulating SM and its EFTs by means of on-shell amplitude methods
  - Field theory in extra dimensions (issue of localization)

QCD & flavour physics — list of research topics:

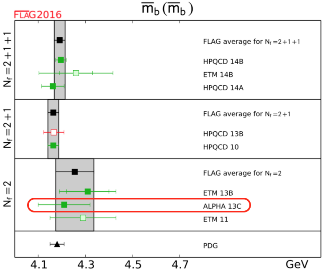
QCD

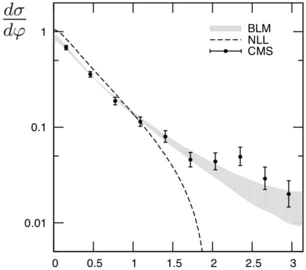
- Effective theories of QCD with applications (ChPT, NRQCD, HQET, SCET)
- Lattice QCD
- Tomography of hadrons and physics of spin [(n)PDF, GPD, TMD]
- Perturbative QCD
- Unitarisation/saturation of QCD at high energies
- Modelling of QCD in soft regime

Flavour physics

- Standard Model as effective theory and its generic extensions
- Flavour physics phenomenology (LHC, Belle II, Bes III, NA62)
- Development of tools for statistical analysis in particle physics phenomenology
- Model building of flavour physics BSM

Highlight: *b*-**quark mass from lattice QCD and effects of resummation**





Determination of the *b*-quark mass

- HQET - QCD fully non-perturbative matching using step scaling
- Renormalization at $\mu \approx m_Z$ matching to $\overline{\text{MS}}$ perturbative
- $m_b^{\overline{\text{MS}}}(m_b) = 4.21(11)$ GeV

Effects of resummation of QCD logs at large energies $\sigma(pp \to jj)$

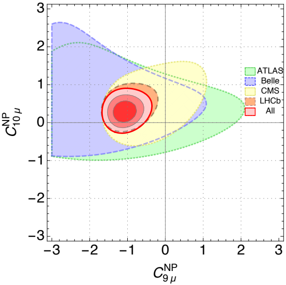
- Azimuthal distribution of jets most forward and most backward in rapidity (Navelet-Muller)
- First complete NLO resummation

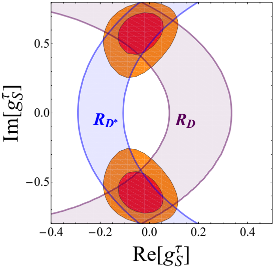
Highlight: B-**physics anomalies**

Several measured observables in exclusive $b \to s\mu\mu$ and $b \to c\tau\nu$ modes differ from SM predictions. Most notably, $R^{\rm exp}_{K^{(*)}} < R^{\rm SM}_{K^{(*)}}$ and $R^{\rm exp}_{D^{(*)}} > R^{\rm SM}_{D^{(*)}}$

$$R_{K^{(*)}} = \frac{\mathcal{B}'(B \to K^{(*)}\mu\mu)}{\mathcal{B}'(B \to K^{(*)}ee)}$$

$$R_{D^{(*)}} = \frac{\mathcal{B}(B \to D^{(*)}\tau\bar{\nu})}{\mathcal{B}(B \to D^{(*)}\ell\bar{\nu})}_{\ell\in(e,\mu)}$$





EFT to constrain specific new physics contributions

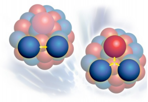
- $C^{\rm NP}_{9\mu}$ short distance $\propto \bar{\mu}\gamma_\mu\mu$
- $C^{\rm NP}_{10\mu}$ short distance $\propto \bar{\mu}\gamma_\mu\gamma_5\mu$

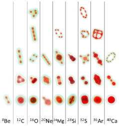
EFT constraint on $g_S = 1/4 g_T$ [R_2 leptoquark scenario]

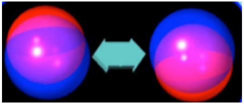
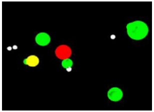
- g_S^τ short distance $\propto \bar{\tau}_R\nu_L$
- g_T^τ short distance $\propto \bar{\tau}_R\sigma_{\mu\nu}\nu_L$

QCD & flavour physics — **Outlook / plans**:

- **QCD**
  - Tomography of hadrons and physics of spin [(n)PDF, GPD, TMD]
  - Model-independent approach to EM corrections in hadronic processes
  - Final-state interaction in B- and D-decays
  - Study of unstable hadrons by means of lattice QCD
  - Mathematical and automated tools for higher-order loop computations
- **Flavour physics**
  - Description and understanding of flavour physics anomalies
  - Flavour constraints on physics BSM
  - Careful assessment of hadronic uncertainties (lattice QCD and EFT/QCD)
  - Theory of flavour (model building)

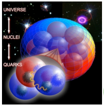


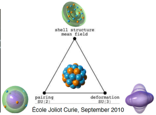


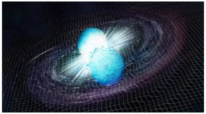
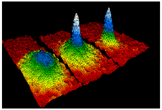
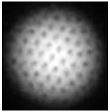



Nuclear physics — list of research topics:

- **Few-body physics**: exact methods, multi-body interaction, universality.
- **Nuclear structure**: many-body techniques, nuclear interaction, shell evolution, clustering, superfluidity.
- **Nuclear reactions**: ab-initio theories, microscopic transport theories, nuclear reaction mechanisms.
- **Interdisciplinary research**: fundamental symmetries in nuclei, nuclear astrophysics, ultracold atoms, . . .

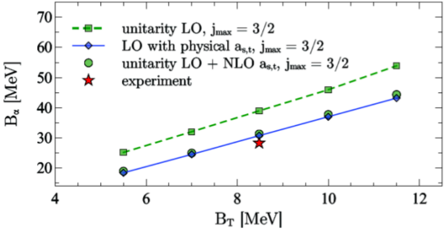




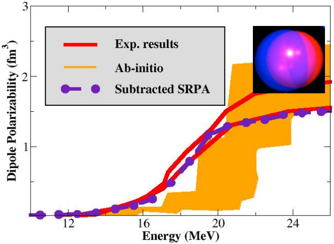




Highlights in **few-body physics** and **nuclear structure**:

Universal aspects in few-body systems: correlation between α-particle and triton binding energies ("Tjon line"): the unitarity limit captures the essential physics.

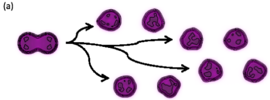


Extraction of the dipole response in strongly correlated systems: calculation of the electric dipole polarizability with an extended random phase approximation (Subtracted SRPA).

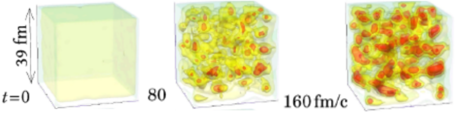


Highlights in **nuclear reactions**:

Stochastic description of many-body dynamics: phase-space methods for dissipation and fluctuations in nuclear fission.

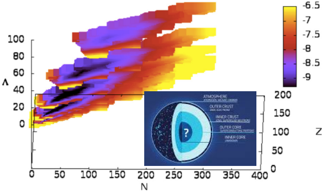


Cluster formation through amplification of initial fluctuations in nuclear matter at subsaturation density.

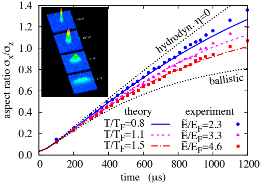


Highlights in **interdisciplinary research**:

Nuclear astrophysics: Hypernuclear chart



Cold atoms expansion



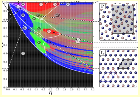
Nuclear physics — **Outlook / plans**:

- **Few-body physics**:
  - Pionless EFT with multi-body interaction, applications to hypernuclei.
  - Ab-initio description of antinucleon-nucleus collisions.
- **Nuclear structure**:
  - From modern ab-initio methods to nuclear density functional theory.
  - Development of novel approaches to describe complex correlations in nuclei: extension of RPA, clustering and configuration mixing.
- **Nuclear reactions**:
  - Role of 3-nucleon force in ab-initio description of halo nuclei.
  - Extensions of time-dependent mean field to describe quantum interferences and fluctuations leading to cluster formation.
- **Interdisciplinary subjects**:
  - Constraints on the nuclear equation of state from gravitational wave signals.
  - Bridging between superfluid cold atoms and neutron stars.
  - Nuclear physics tests of fundamental symmetries using EFT.

Statistical physics — list of research topics:

Equilibrium

Long-range interactions
- Bilayers with Coulomb interactions
- Melting of 2D crystals
- Coulomb fluids or plasmas on the hypersphere



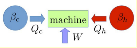
Out-of-equilibrium

Fundamental questions

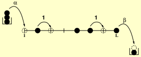
Thermodynamics of out-of-equilibrium systems: developped on simple models

Fluctuations

- Small machines



- Exclusion Processes



- Spin chains

Example of result: New class of fluctuation relations for first passage times in renewal processes

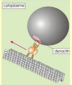
Applications

Pedestrians

Road trafic

Inter-disciplinary work

Intracellular transport
→ see Health Physics presentation



Data analysis ⇄ **Modeling**

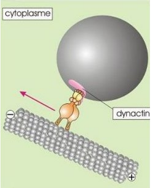
Highlight: **Thermodynamics of out-of-equilibrium systems**

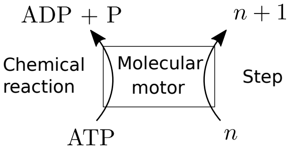
Proposal of a new general frame

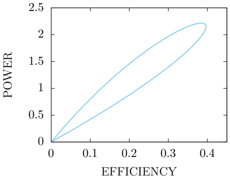
Non-linear conductances: relate currents and forces (non-linear version of Onsager relations) ➡ allows in particular to study the compromise between power and efficiency.

Example: a **molecular motor**

- chemical energy is transformed into mechanical energy
- thermal fluctuations play a role







Statistical physics — **Outlook / plans** (a few highlights):

Long-range many-body systems

- New algorithm for molecular dynamics simulations on the hypersphere ➡ Ex: frequency dependent dielectric constant of a polar fluid

Out-of-equilibrium

- New types of small machines:
  — cyclic
  — with phase transitions
  — with emergent oscillations

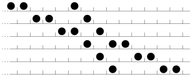
- Search for self time-averaging regimes (≃ almost ergodic) in a non ergodic model (variant of Game of Life)

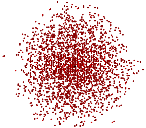
Statistical physics and biology

- ions near biological membranes
- cellular automata as evolutionary systems

Interface physics - life sciences — list of research topics:

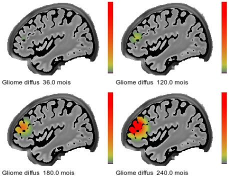
Integrability of discrete dynamical systems

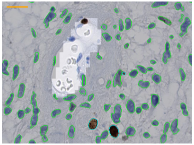




Statistical physics of out-of-equilibrium complex systems (analytic + Monte-Carlo)

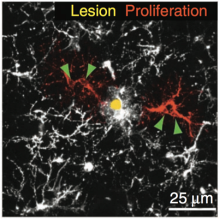
Theoretical modelling of brain tumours and populations of cells (with PDE, agent-based models, . . .) based on clinical + in vitro data

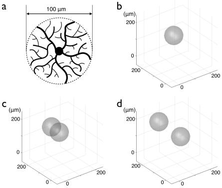




Big data approach to brain tissue samples (10^9 pixels per image)

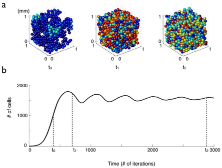
Highlight: **brain tumour research**

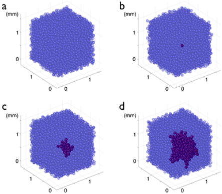




In vivo experiments with oligodendrocyte precursor cells

→ model of collective behaviour of these cells (incl. proliferation and density-dependent death)





→ discriminate between scenarios of birth of brain tumours, namely acquisition by cells of

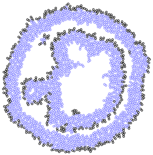
(a) immortality,

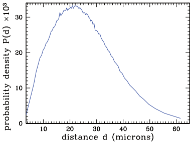
(b) contact-inhibition-free proliferation,

(c) higher proliferation rate.

Interface physics - life sciences — **Outlook / plans**:

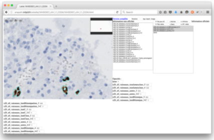
Make models of collective cell behaviour more realistic, including shape of cells and proliferation and exploring effects of environment and crowding

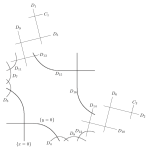




Exploit spatial organisation of tumour tissue (big data!): on 2D tissue images & on 3D samples

Industrial exploitation of big image analysis for tumour diagnosis





Keep world-class expertise in integrability of discrete dynamical systems

Theory group — **Strengths**:

- The theory group is very **active and productive** and has a very strong and nationally and internationally **recognized expertise** in its research areas.
- The theory group is **multi-disciplinary**, its members involved in a wide range of fields of theoretical physics.
- The teams have many local, national, and international **collaborations**, both in theory and experiment, and belong to many European and bilateral **networks**.
- The group has an excellent track record in training **PhD students and postdocs**, and it has a strong involvement in **teaching** at various levels.

Theory group — **Weaknesses**:

- The number of PhD students has dropped significantly over the past years.
  - In the LPT, the problem is the **lack of PhD grants** so that only a few of the good and interested students can be accepted.
  - In the IPN, the **lack of University professors** limits the interaction with students and the representation of its research topics in Univ. programs.
- Some teams have a **bad equilibrium** of University and CNRS personnel.
- It is becoming more and more **difficult to obtain financial grants**, leading to a large reduction in the number of postdocs and making it harder to maintain international collaborations. Made worse by continuous decrease of lab budgets.
- **Common projects** among the permanent members of a team and between the different teams are relatively **rare**.

Theory group — **Opportunities**:

- Interesting prospects for **scientific collaborations** with neighbouring theoretical and experimental groups, potentially enhanced through the fusion of the 5 labs.
- The fusion of the 5 labs might open up **additional funding** possibilities for theory, simply by being part of a larger structure with more financial resources or through new collaborations with its experimental groups.
- The fusion might open up access to more extensive **computer services**.
- The infrastructure project would allow construction of a real **theory centre**, increasing the **visibility and attractiveness** of theoretical physics in the Valley.
- **Major experimental/observational advances** are expected in the coming years in many of the fields that the members of the theory group are active in.

Theory group — **Threats**:

- The theory group has shrunk significantly, making it difficult to continue research at the same level as in the past. **Prospects for future hirings remain bleak** and many **more retirements** will happen in the next years. The size of **certain teams might become sub-critical**.
- There is a **risk to the visibility** of the theory group due to the fusion into a larger experimental lab. There is a **risk to the involvement in teaching** due to the imminent retirement of several University professors. These could negatively impact the ability to attract good students and postdocs.
- A **continuing lack of students, postdocs and of financial support** will be very damaging. The repetition of grant applications is quite time-consuming.
- While increased involvement with the experiments in the new, predominantly IN2P3, lab is welcome, the theory group must maintain its link with the INP, in order to avoid any **risks to its multi-disciplinarity**.

BACKUP SLIDES

All permanent staff of the theory group on 30 June 2018 (no emeritus researchers)

1. Mathematical physics (LPT 4)
   - Dario BENEDETTI (C)
   - Vincent RIVASSEAU (U)
   - Jean-Christophe WALLET (C)
   - Robin ZEGERS (U)
2. Cosmology & gravitation (LPT 4)
   - Eugeny BABICHEV (C)
   - Christos CHARMOUSIS (C)
   - Renaud PARENTANI (U)
   - Bartjan VAN TENT (U)
3. Higgs Sector & physics BSM (LPT 6)
   - Asmâa ABADA (U)
   - Abdelhak DJOUADI (C)
   - Ulrich ELLWANGER (U)
   - Adam FALKOWSKI (C)
   - Yann MAMBRINI (C)
   - Grégory MOREAU (U)
4. QCD & flavour physics (LPT 5 + IPN 4 + LAL 1)
   - Damir BECIREVIC (LPT, C)
   - Benoît BLOSSIER (LPT, C)
   - Philippe BOUCAUD (LPT, C)
   - Sébastien DESCOTES-GENON (LPT, C)
   - Samuel WALLON (LPT, U)
   - Véronique BERNARD (IPN, C)
   - Samuel FRIOT (IPN, U)
   - Jean-Philippe LANSBERG (IPN, C)
   - Bachir MOUSSALLAM (IPN, C)
   - Emi KOU BOURHIS (LAL, C)
5. Nuclear physics (IPN 8)
   - Jaume CARBONELL (C)
   - Marcella GRASSO (C)
   - Guillaume HUPIN (C)
   - Elias KHAN (U)
   - Denis LACROIX (C)
   - Paolo NAPOLITANI (C)
   - Michael URBAN (C)
   - Ubirajara VAN KOLCK (C)
6. Statistical Physics (LPT 4)
   - Cécile APPERT-ROLLAND (C)
   - Françoise CORNU (C)
   - Martial MAZARS (U)
   - Gatien VERLEY (U)
7. Interface physics - life sciences (IMNC 3)
   - Mathilde BADOUAL (U)
   - Christophe DEROULERS (U)
   - Basile GRAMMATICOS (U)

U = University, C = CNRS

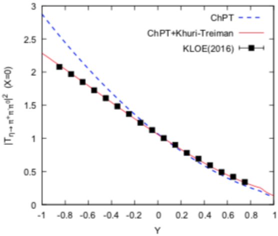
B. Moussallam

New applications of analyticity in soft QCD

→ New $\eta \to 3\pi$ experiments: [KLOE(2016), BESIII(2015), WASA (2014) ...] : measure $m_d - m_u$ from data ?

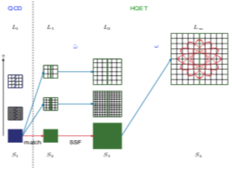
→ Old problem of low-energy eff. theory (ChPT): slow convergence in *physical region*

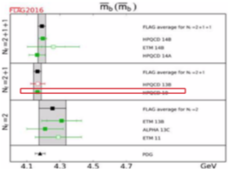
→ Solution: use Khuri-Treiman dispersive equations + matching with ChPT in *unphysical region*

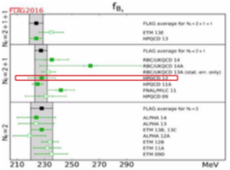


→ Ref. [Albaladejo, Moussallam, EPJ C77,508 (2017)]

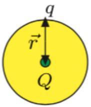
- B-physics properties: b-quark mass m_b, B_s decay constant f_{B_s} from lattice QCD
Non perturbative matching of Heavy Quark Effective Theory (HQET) with QCD: systematic control of cut-off effects Strategy OK to pass quality criteria established by the Flavour Lattice Averaging Group.

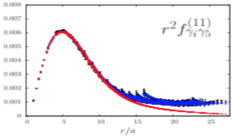


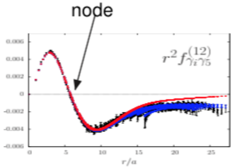




- Probe the internal structure of B mesons in the $m_Q \to \infty$ limit of HQET: correlation functions show similar patterns to the wave functions of quantum mechanics regarding radial excitations. Understanding of the dynamics to explain values of soft pion couplings to B.

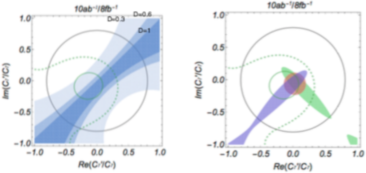




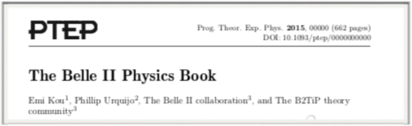


The photon polarisation of b->s γ: we found a new observable in the B->Kππγ time-dependent CP violation measurement, which allows us to determiner the complex coupling (C7'/C7) unambiguously. arXiv:1802.09433

w/o new observable *w/ new observable*



Summary of 4 years activity of Belle II physics working group, B2TiP (Belle II Theory interface Platform). arXiv:1808.1056

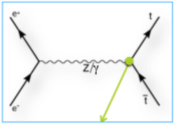

PTEP

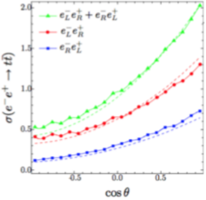
Prog. Theor. Exp. Phys. **2015**, 00000 (662 pages)
DOI: 10.1093/ptep/0000000000

The Belle II Physics Book

Emi Kou[1], Phillip Urquijo[2], The Belle II collaboration[3], and The B2TiP theory community[3]

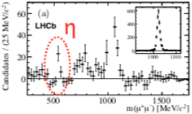
Studying the e+e- ---> ttbar at ILC targeting a signal beyond SM. Taking into account the electroweak NLO correction (never done before) and performing sensitivity study by the matrix element method. arXiv:1503.04247



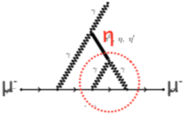


An extremely rare D meson decay, η->μ⁺μ⁻ is observed in the background of LHCb study of D->π⁺μ⁺μ⁻. We investigated theoretical importance to study this decay and future prospect at upgrade of LHCb. arXiv:1606.08195

$D^+ \to \pi^+ \mu^+ \mu^-$



g-2 LbL



S. Friot

Analytic representation of F_K/F_π in two loop chiral perturbation theory

B. Ananthanarayan, S. Friot, J. Bijnens and S. Ghosh, Phys. Rev. D 97, 091502 (2018)

The ratio F_K/F_π can be used to compute the CKM matrix element $|V_{us}|$, an important ingredient to put bounds on extensions of the Standard Model of particle physics.

We have been able to compute analytically F_K/F_π in the framework of an effective field theory of QCD at low energies, namely Chiral Perturbation Theory (ChPT) with three flavors, at the two-loop level.

This requires solving the long standing problem of evaluating on-shell sunset diagrams with three different mass scales, whose analytic expressions were unknown for the physical masses of the light pseudoscalars.

With the help of the Mellin-Barnes computational method we have derived expressions of the sunsets in terms of Kampé de Fériet double hypergeometric series.

Thanks to some available lattice evaluation of F_K/F_π, it is now possible to perform fits of our expression with the aim to extract values of the ChPT low energy constants L_5, $C_{14}+C_{15}$ and $C_{15}+2C_{17}$.

Evidence for Gluon Shadowing in Nuclei in the LHC Heavy-Flavour Data

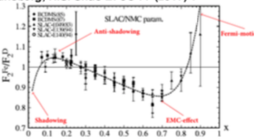
A. Kusina, I. Schienbein, J.P. Lansberg, H.S. Shao PRL 121 (2018) 052004 & J.P. Lansberg, H.S. Shao EPJC 77 (2017) 1

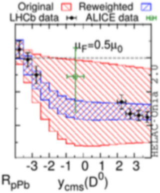
- Different dynamics of the quarks in nuclei than in nucleons [Fermi-motion, EMC effect, (anti)-shadowing]
- Encoded in nuclear PDFs (Parton Distribution Functions)
- For gluons : no experimental evidence so far
- Scale evolution relates the quark & gluon dynamics
- Charm, beauty and quarkonium ($Q\bar{Q}$) production is suppressed in proton-nucleus collisions
- Many competing effects at low energies but, at LHC energies, nPDF effects inferred from the quark dynamics (through global nPDF fits) reproduce the data, but with large uncertainties
- Reweighting Bayesian technique allowed us to use these heavy-flavour data to further constrain the gluon nPDF

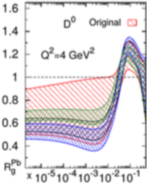
$\Rightarrow$ **Evidence for shadowing**

The gluon distribution is suppressed in nuclei at momentum fractions below 1%

- Same technique used for physics projections for AFTER@LHC (LHC Fixed-Target Experiment, 1807.00603)

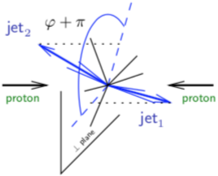


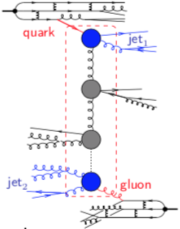




S. Wallon

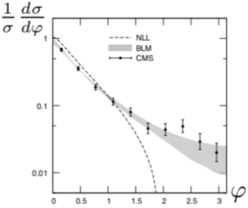
Most promising observable for high-energy resummation effects:
Mueller-Navelet dijets (1987) at the LHC





LHC: very large available energy !

emitting many soft partons does not cost too much
$\Rightarrow$ large cross-section + decorrelation (e.m. conservation): $\varphi \neq 0$

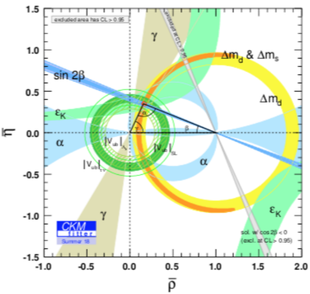


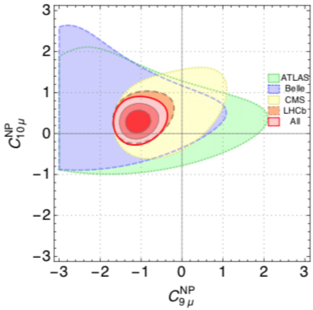
- first complete next-to-leading resummation of energy logarithms
- first experimental sign of high energy QCD resummation effects at the LHC (CMS)

B. Ducloué, L. Szymanowski, S. Wallon, *PRL 112 (2014) 082003*

CKM fitter group (~ 10 exp + theo)

- Global statistical analysis of quark flavour transitions (e.g. CP violation)
- SM: Metrology of the CKM matrix
- Beyond: Constraints and prospective on simple NP models





Rare $b \to s\ell\ell$ transitions (B anomalies)

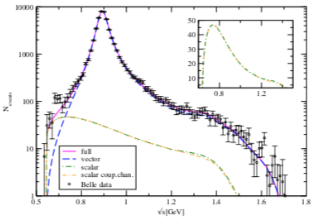
- deviations observed by LHCb
- consistent EFT interpretation as specific (short-dist) NP contribs.
- study of (long-dist.) QCD uncert.
- new observables ($b \to s\tau\tau$, LFUV obs) to test NP scenarios

TEST OF THE SM: DETERMINATION OF $f_+(0)V_{us}$

Combined analysis of $\tau \to K\pi\nu_\tau$, $K\pi$ scatt. & constraints from K_{l_3}

- VECTOR CHANNEL: N/D approach with coupled channels $\to$ good properties of unitarity and analyticity and PREDICTION FOR $\tau \to K^*\pi$
- SCALAR CHANNEL: Dispersive approach: twice subtracted $\to$ one parameter $C \equiv f_0(M_K^2 - M_\pi^2)/f_0(0)$.

FROM CALLAN TREIMAN theorem ($SU(2) \times SU(2)$):
$C = F_K/(F_\pi f_+^{K\pi}(0)) + \Delta_{CT}$ Δ_{CT} small correction $\leftarrow$ CHPT



VERY GOOD FIT OF $\tau \to K\pi\nu_\tau$ AND $K\pi$

$|f_+(0)V_{us}| = 0.2163 \pm 0.0014$

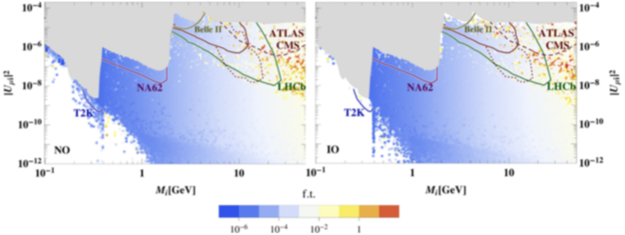
$\ln C = 0.2062 \pm 0.0089$

COMPATIBLE WITH SM

MORE PRECISE EXPERIMENTS NEEDED

Baryon Asymmetry of the Universe via *testable* Leptogenesis

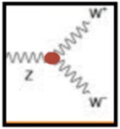
- Standard Model of Particle Physics extended with 3 right-handed neutrinos with masses below the EW scale can provide a simultaneous explanation for both neutrino masses (and lepton mixing) and the BAU,
- a relevant fraction of the resulting parameter space can be tested by already running experiments, including ATLAS, CMS, LHCb, NA62, T2K and Belle II,
- and of planned future facilities like SHiP, FCC-ee and LBNF/DUNE



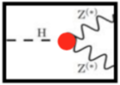
Active-sterile mixing in the muon flavour for viable BAU as a function of the heavy neutrino mass, for a normal (left) and inverted (right) ordering in the light neutrino mass spectrum. The grey region is experimentally excluded, while the lines show the expected sensitivities for ongoing experiments

Higgs vs Precision synergy

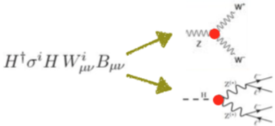
SM predicts triple gauge vertices in terms of well measured gauge couplings. Deviations from these predictions parametrized by anomalous triple gauge couplings δg_1^Z $\delta\kappa_\gamma$ and probed by electroweak precision measurements at LEP



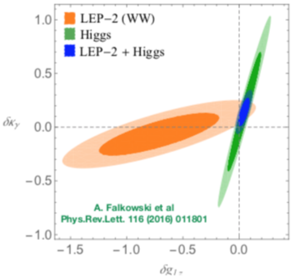
SM predicts Higgs couplings to matter in terms of well measured particle masses Deviations from these predictions parametrized by anomalous Higgs couplings and probed by Higgs precision measurements at LHC



Effective field theory predicts model independent correlations between those two

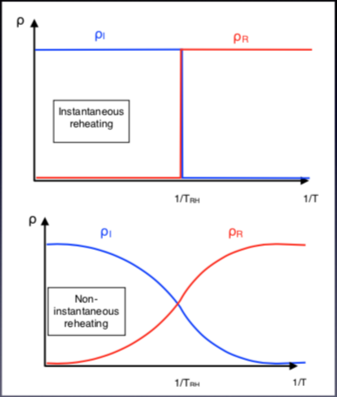


Much stronger constraints obtained thanks to combining electroweak precision and LHC Higgs data!



Before the end of the reheating process, while the Universe was still dominated by the matter (inflaton), temperature was higher than T_{RH}

We showed that dark matter production can be boosted up to 6 order of magnitudes at this epoch depending on energy (temperature) dependance of the production cross section when we consider non-instantaneous reheating.



Y. Mambrini

We had to solve the system of coupled equations for the inflaton I the radiation R and the dark matter χ :

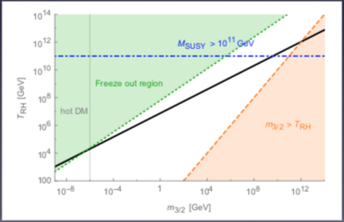
$$\frac{d\rho_I}{dt} + 3H\rho_I = -\Gamma_I \rho_I$$

$$\frac{d\rho_R}{dt} + 4H\rho_R = \Gamma_I \rho_I$$

$$\frac{dn_\chi}{dt} + 3H\, n_\chi = R(T)$$

$$H^2 = \frac{\rho_I}{3M_P^2} + \frac{\rho_R}{3M_P^2}$$

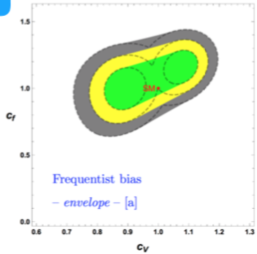
We applied it in High Scale SUSY, SO(10), Massive gravity and String inspired models



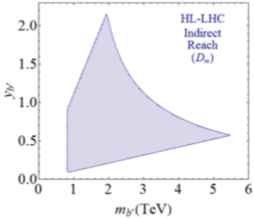
Example of a new parameter space we opened once we consider production of gravitino dark matter in the early Universe.

G. Moreau

Elementary particle theory and phenomenology beyond the Standard Model



- **Fits of the couplings of the Higgs boson** discovered in 2012 (ElectroWeak mechanism) with effective corrective factors c_V and c_f on respective couplings HVV and Hff. Rigorous statistical treatment of the **theoretical errors** (becoming relatively important) on rates and their **correlations** (including prior shape analysis). Comparing Bayesian versus frequentist approaches and **bias versus marginalisation**.



- **High sensitivity for the LHC test of an effective extra vector-like quark** b' (Kaluza-Klein, composite state) in a minimal model obtained, via $b - b'$ mixing effects in the Higgs Yukawa coupling to the bottom quark, from a 5% accuracy expected at the HL-LHC (3000fb^{-1}) on the measurement of $\Gamma(H \to b\bar{b})/\Gamma(H \to WW^\star)$ thanks to **compensated theoretical uncertainties** at the Higgs production level.

- **Formal analysis of the regularisation of a scalar field localised** at the boundary of extra spatial dimensions. Understanding – based on the comparison of 4D / 5D methods – of a **non-commutativity paradox**: the calculation ordering, between the limits $N_{\text{Kaluza-Klein}} \to \infty$ and $\epsilon_{\text{regularisation}} \to 0$, was leading to two different mass spectra (!) for fermions coupled to this scalar field and propagating along those extra dimensions.